Determination of the $^{41}Ca(n,\alpha)^{38}Ar$ cross section up to 80 keV neutron energy

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Collaboration:

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irmm
Institute for Reference Materials and Measurements

Introduction

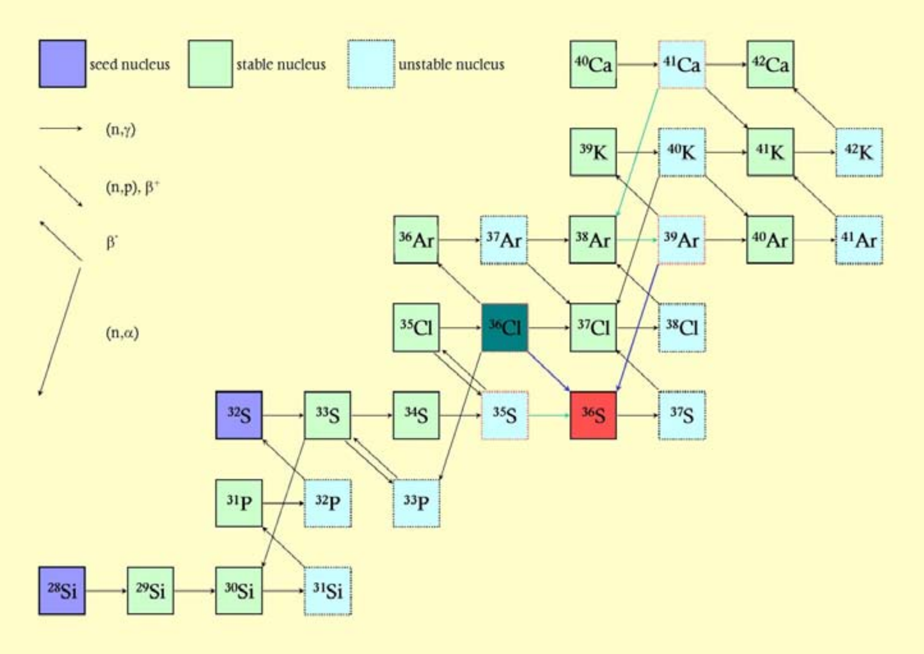
Why do we measure $^{41}Ca(n,\alpha)^{38}Ar$? (1)

- no previous measurements in the resonance region
- important to answer the question about the origin of ^{36}S

→ ^{36}S is believed to be synthesized during the weak s-process

to check this hypothesis:
nucleosynthesis network calculations
in mass region $28 \leq A \leq 42$ are necessary

$^{41}Ca(n,\alpha)$ reaction recycles to ^{36}S via the following reaction chain:
$^{41}Ca(n,\alpha)^{38}Ar(n,\gamma)^{39}Ar(n,\alpha)^{36}S$



Introduction

Why do we measure $^{41}Ca(n,\alpha)^{38}Ar$? (2)

$^{41}Ca(n,\alpha)$ reaction strongly dominates over the
$^{41}Ca(n,\gamma)$ reaction in the resonance region

↓

Maxwellian averaged cross section (MACS) at stellar temperatures
of importance for s-process nucleosynthesis in stars
will be larger for $^{41}Ca(n,\alpha)$ than for $^{41}Ca(n,\gamma)$

↓

branching in the nucleosynthesis path

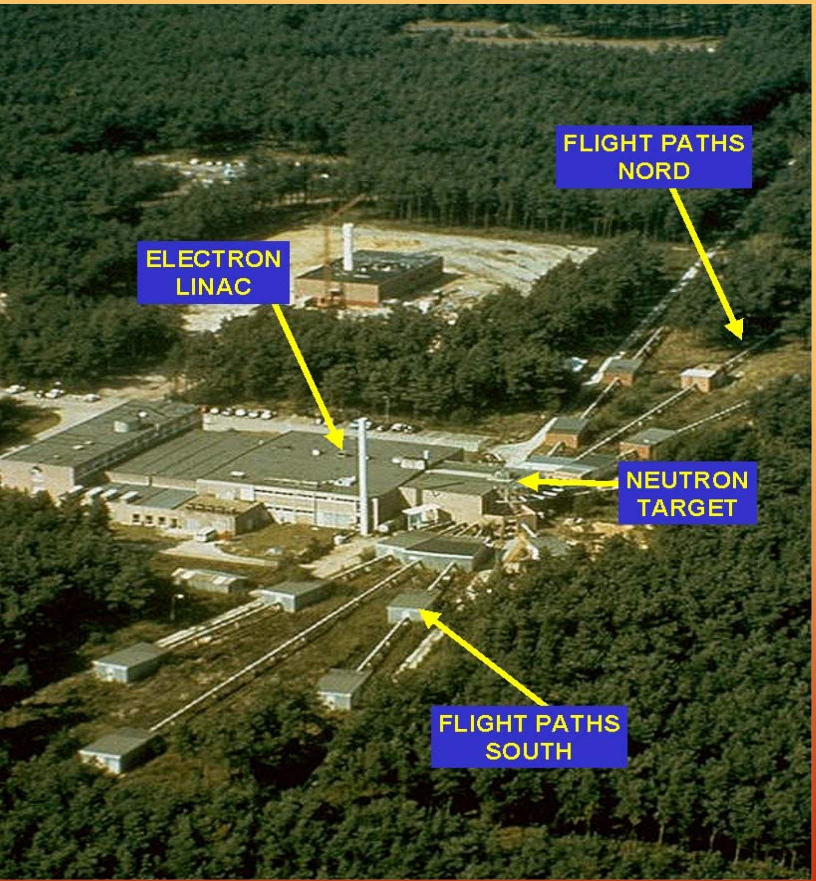
- determination of the MACS

→ verify theoretical MACS values

Experimental setup

GELINA neutron time-of-flight facility

(Institute for Reference Materials and Measurements (IRMM) Geel, Belgium)



- Frisch gridded ionization chamber with methane as detector gas
- 2π geometry
- accelerator: 800 Hz repetition frequency

Experimental setup

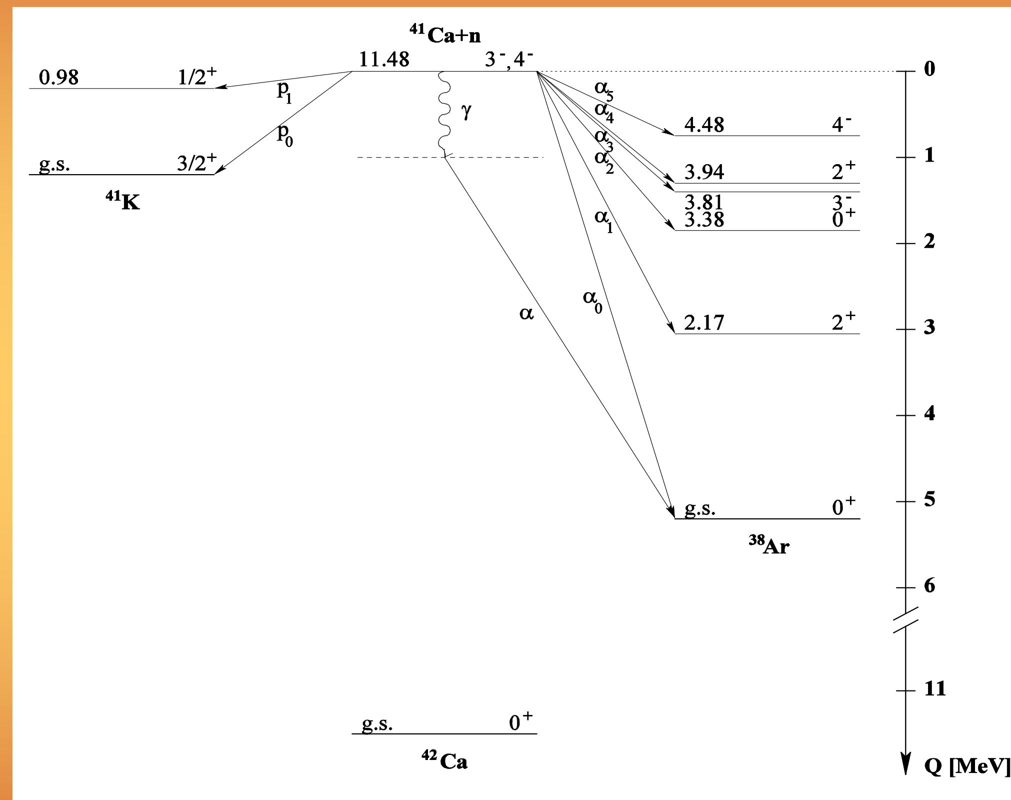
two different measurement campaigns to determine reaction cross section

- at 8.5 m flight path → measured by L. De Smet (2006)
- at 30 m fligth path → to improve the energy resolution and to extend the energy range

  - remove neutrons from previous bursts: boron overlap filter
  - time dependent background:
    determined in a separate measurement
    putting black resonance filters such as
    Au, Co, Mn, Rh, W and Al in the neutron beam

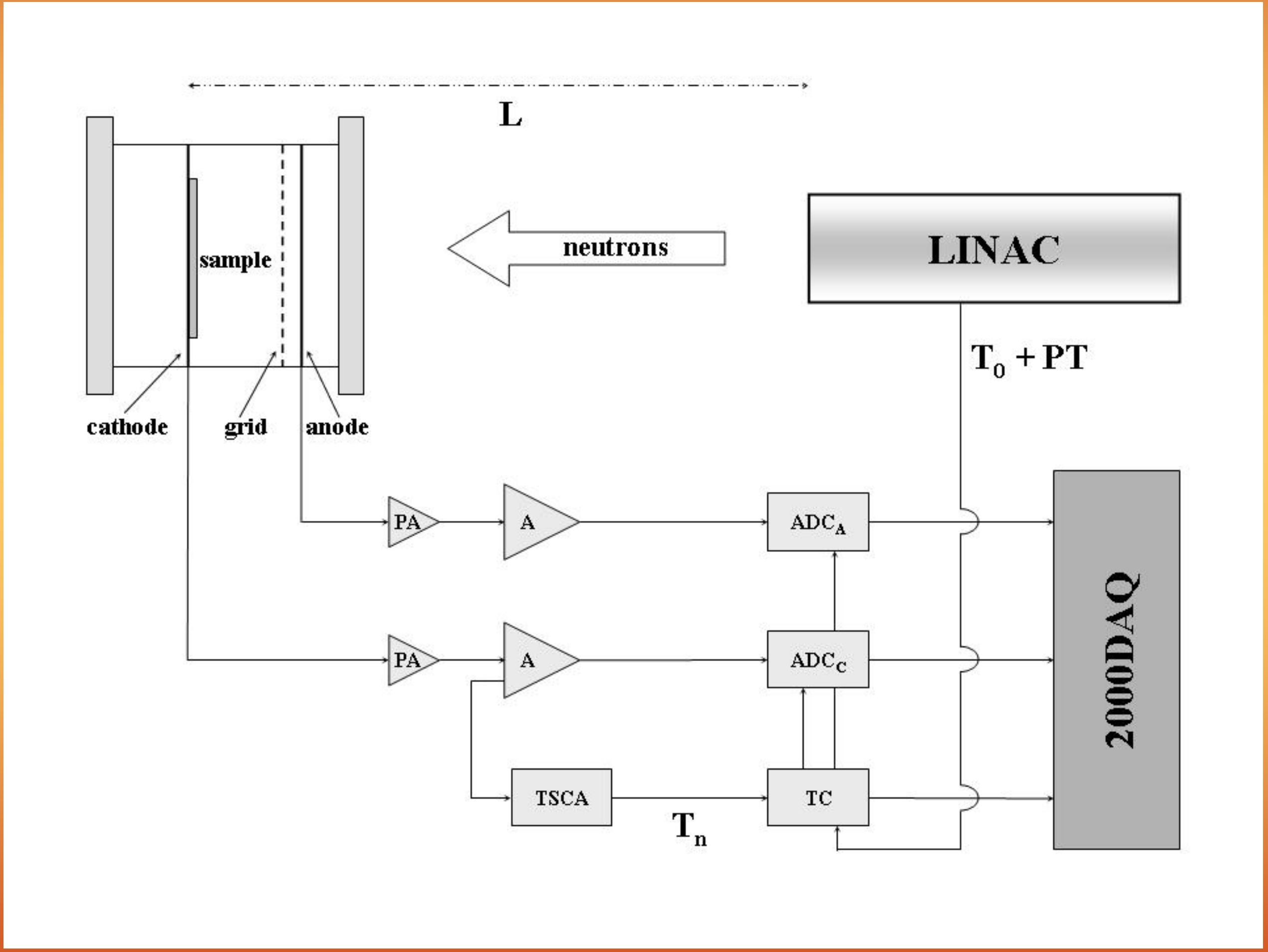
Experimental setup

^{41}Ca: both (n,α) and (n,p) reactions are possible



the settings of the ionization chamber were adjusted to detect only the α-particles

Experimental setup



Experimental setup

Samples

- ^{41}Ca sample

  prepared at IRMM

  suspension spraying in methanol on an aluminium foil

  enrichment 63.38 %

  effective area 6 × 5 cm

  $(4.08 \pm 0.40) \times 10^{18}$ atoms

  → uncertainty is mainly due to the uncertainty on the ^{41}Ca half-life = $(1.02 \pm 0.07) \times 10^{5}$ y

- ^{10}B: neutron flux determination

  $(8.51 \pm 0.43) \times 10^{19}$ atoms

Data reduction

- Total observed counting rate $Y_{Ca}(E_n)$:

$$Y_{Ca}(E_n) = \varepsilon_{Ca} N_{Ca} \sigma_{Ca}(E_n) \varphi(E_n) + Y_{Ca}^{BG}(E_n) \quad (1)$$

detector efficiency

number of atoms in the ^{41}Ca sample

differential neutron induced cross section to be determined

neutron flux

time dependent background

- Similar relation for the flux counting rate ^{10}B(n,α) (2)

dividing (1) and (2):

$$\sigma_{Ca}(E_n) = \frac{\varepsilon_B}{\varepsilon_{Ca}} \frac{Y_{Ca}(E_n) - Y_{Ca}^{BG}(E_n)}{Y_B(E_n) - Y_B^{BG}(E_n)} \frac{N_B}{N_{Ca}} \sigma_B(E_n)$$

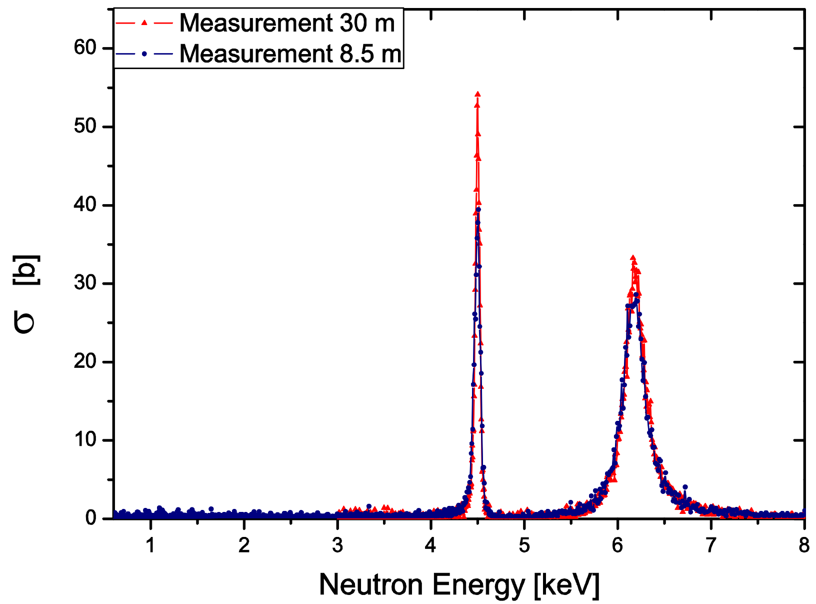
= 1

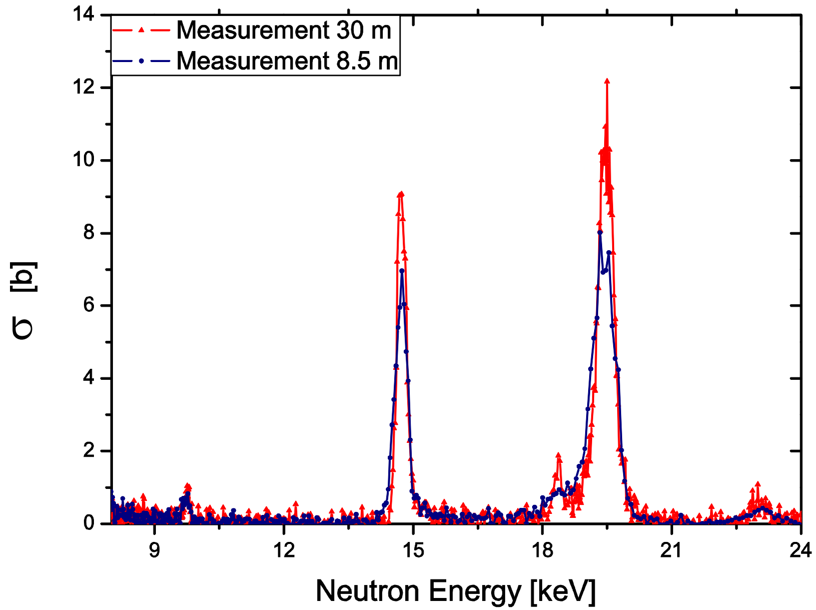
from ENDF/B-VII

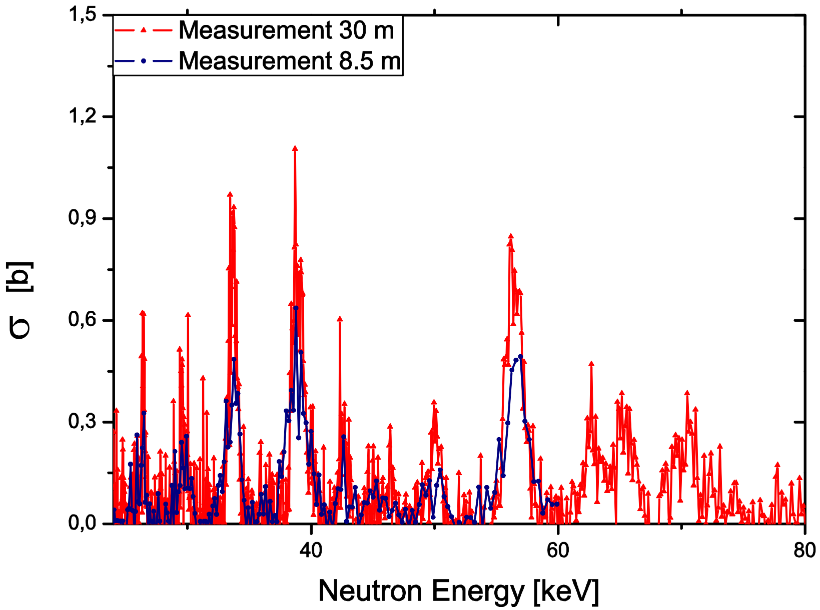
Results: Cross section

Data analysis: AGS

computer code for data reduction and uncertainty propagation in time-of-flight cross section data, which was developed at IRMM







Results: Resonance analysis

- Determination of the resonance parameters: influenced by the broadening of the resonances due to the experimental resolution

- Fitting of the resonances:

  parameters →

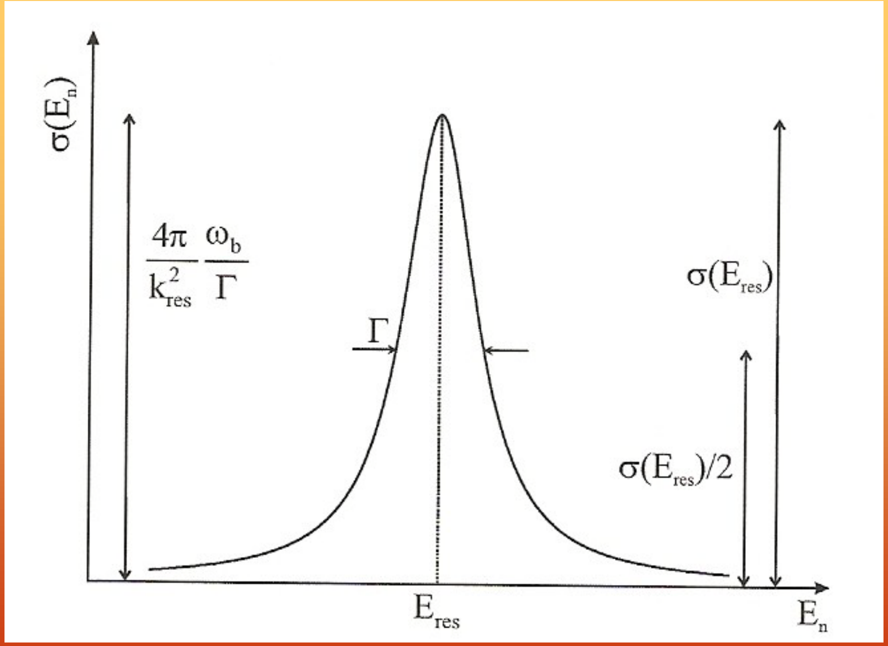
E_{res}: resonance position

Γ: total level width

A_{res}: area of the resonance

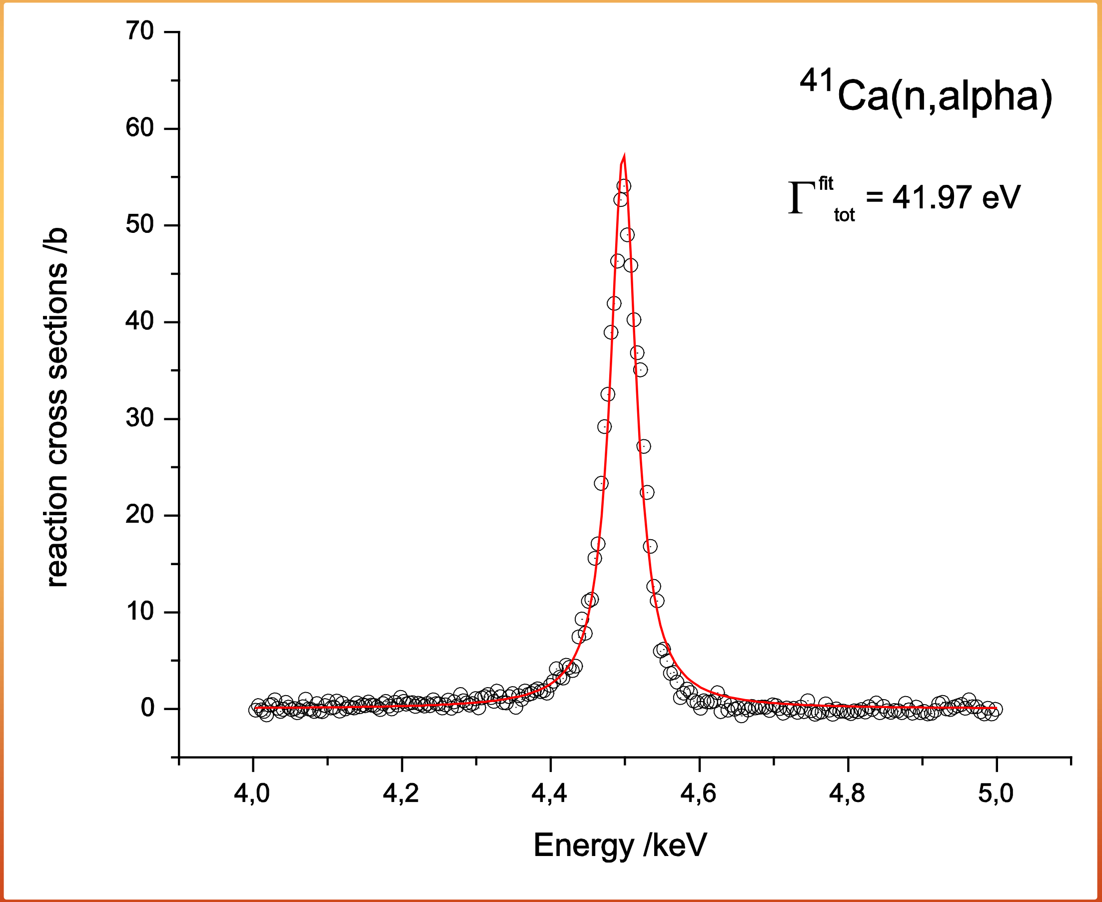
ω_α: resonance strength

with $A_{res} = 2\left(\frac{\pi}{k_{res}}\right)^2 \omega_\alpha$



Results: Resonance analysis

Fit of the first resonance: preliminary result obtained with SAMMY code



Astrophysical implications: MACS

Numerical integration of the obtained (n,α) cross section data:

$$\langle\sigma\rangle = \frac{2}{\sqrt{\pi}}\frac{1}{(kT)^2}\int_0^{+\infty}\sigma(E_\mu)E_\mu e^{\frac{E_\mu}{kT}}dE_\mu$$

up to 20 keV: good agreement

above 20 keV: 30 m results are higher

as expected!

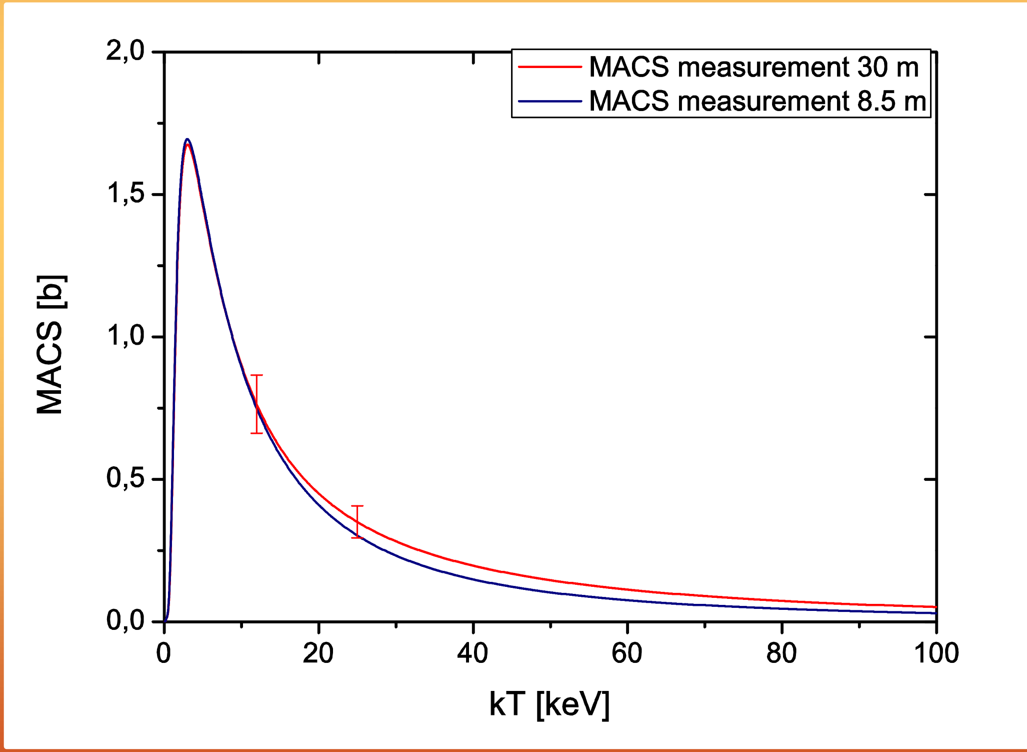
8.5 m: data up to 45 keV

30 m: data up to 80 keV

resonance at energy E_{res}

maximum contribution at kT = 0.5 E_{res}

8.5 m: MACS values > 22 keV: lower limits

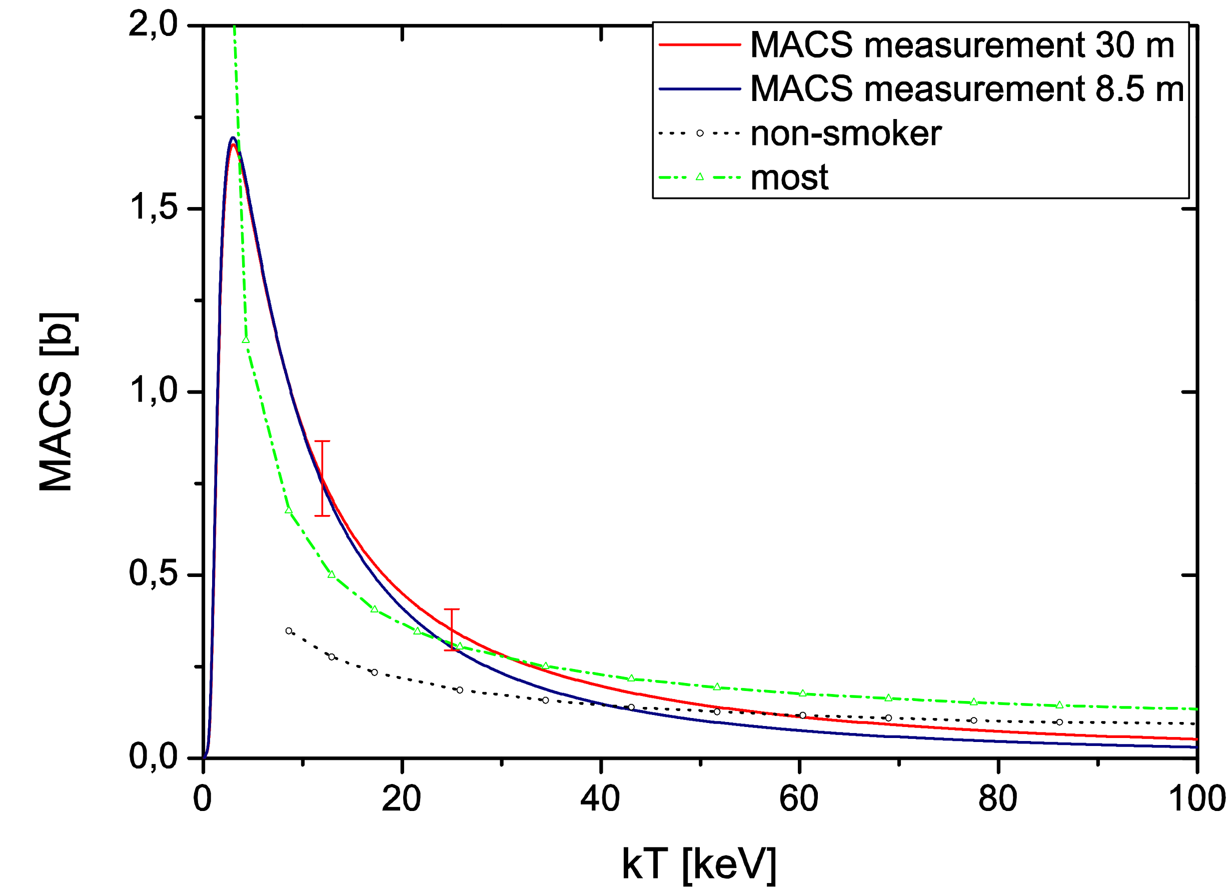


Astrophysical implications: MACS

Comparison between experimental and theoretical values

MOST NON-SMOKER

some stellar temperatures are of particular interest to s-process calculations: 8, 12 and 25 keV



MACS value at 8 keV
> both theoretical values

MACS value at 25 keV
= MOST value

Conclusion

- $^{41}Ca(n,\alpha)^{38}Ar$ cross section measurement: first results in the resonance region
- comparison between theoretical and experimental MACS values: MOST gives the best results
- resonance analysis ongoing to determine resonance parameters, which are not available yet in the literature